Supporting Information to the manuscript entitled

# Contribution of Li-ion batteries to the environmental impact of electric vehicles

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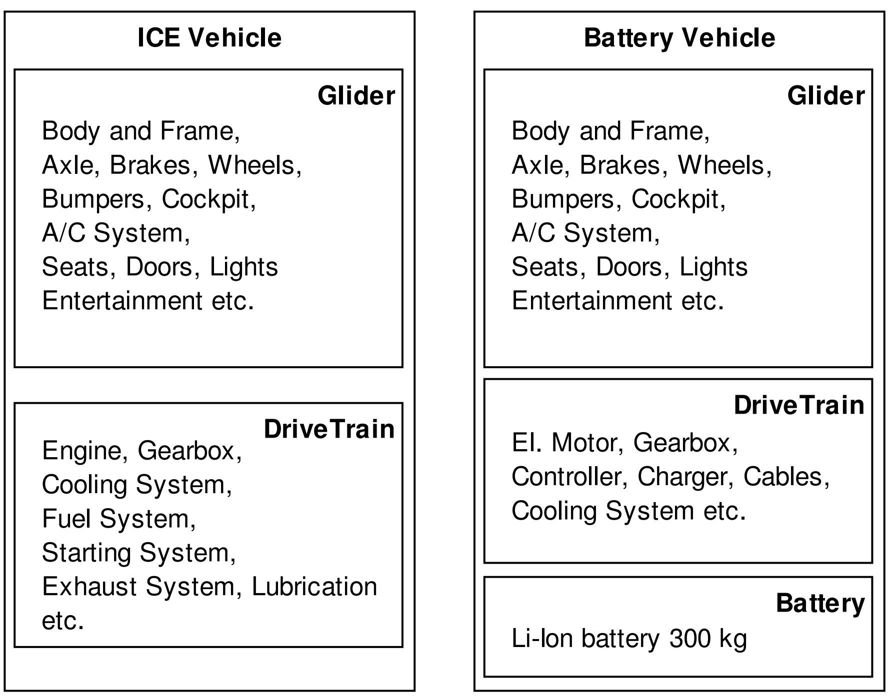
## Electric vehicle production and disposal

A typical middle-class passenger car from ecoinvent v2.0, represented by a Golf A4 (petrol, 55kW) is used as a base for the LCI [1]. This dataset originates on data from "Life Cycle Inventory for the Golf A4", a “Volkswagen” report from the year 2000 [2]. All sub-components constituting the ICE drive train were subtracted from the ecoinvent dataset, leaving the LCI of a motor less vehicle glider. Thus, two new LCI datasets for a Glider and an ICE drive train were generated which combined match the Golf A4 (Table S1 to S3). A new LCI dataset for an electric drive train was generated using data Brusa [3-5]. The components to build an LCI for an electric drive train are selected in such a way, that the same maximal permanent power of 55 kW followed from the ICE drive train. The LCI for the entire BEV finally consists of the LCI of the glider, the electric drive train and the Li-ion battery.

**Scheme S1.** The model of an internal combustion vehicle (ICE Vehicle) and a battery vehicle.




Using the same glider for both the ICEV and the BEV allows a fair comparison between the two cars in terms of space, comfort and top speed (171 km/h (106 mph)). Differences appear in acceleration

(BEV: 85 Nm nominal torque, max. 223 Nm; ICEV: 128 Nm) and in driving autonomy (ICEV approximately 820 km with 50 liter-tank and 6.1 liter per 100 km; BEV maximal 200 km with 34 kWh battery and 17 kWh/100 km).

The dataset for maintenance and disposal of the passenger car in ecoinvent has been used for this ICEV vehicle and the BEV with exception of the lead acid battery replacement in case of the BEV.

The energy consumption of the electric vehicle's operation is estimated based on existing vehicles and theoretical considerations. 14.1 kWh of electric energy is needed per 100 km to propel a golf-class vehicle with an overall efficiency of 80% (including charging losses and recuperation gains) in a standard driving cycle (New European Driving Cycle, NEDC). This energy consumption refers to a combination of the urban (12.8 kWh/100km) and extra-urban (16.8 kWh/100km) energy consumption in a NEDC and is calculated based on mechanical energy considerations and efficiency.

Auxiliary energy consumption for heating accounts for 2 kWh/100km. The energy consumption for heating is calculated assuming that there is a heating demand of four month within a year. In addition, 0.5 kWh/100 km electric energy is needed for air conditioning. The energy consumption for air conditioning is calculated assuming that there is an air conditioning demand of four month within a year. Other electricity consumer (light, windshield wiper, ventilation, radio, navigation) need 0.5 kWh/100km based on the assumption that each of these consumers is utilized during 50% of the time the BEV is in use. Heating, cooling and electronic devices consume altogether 2.9 kWh/100 km. The BEV thus requires in total 17 kWh/100 km.

**Reference vehicle**

The ICEV consumes 5.2 liters of gasoline per 100 km in the NEDC plus 0.9 litres per 100 km for air conditioning, electronics etc., resulting in a direct emission of 0.14 kg $CO_2$ per km .

## Inventory for the Glider

**Table S1.** Detailed life cycle inventory for the glider

| Phase | Component | Sub1 | Sub2 | Ecoinvent composition | Unit | Amount in vehicle [kg] | Waste factor | Amount in EI [kg] |
|---|---|---|---|---|---|---|---|---|
| production | Glider | Body&Frame | Chassis and body, sheet | reinforcing steel, at plant | kg | 283 | 1.5 | 424.5 |
| production | Glider | Body&Frame | Gaskets EPDM | Synthetic rubber, at plant/RER U | kg | 10 | 1 | 10 |
| production | Glider | Body&Frame | Front screen | Flat glass, uncoated, at plant/RER U | kg | 10 | 1 | 10 |
| production | Glider | Body&Frame | Zinc coating | Zinc, primary, at regional storage/RER U | kg | 6 | 1 | 6 |
| production | Glider | Body&Frame | Insulation | glass fibre reinforced plastic, polyester, hand-lamina | kg | 6 | 1 | 6 |
| production | Glider | Body&Frame | Paint | Alkyd paint, white, 60% in H2O, at plant/RER U | kg | 4 | 1.1 | 4.4 |
| production | Glider | Body&Frame | Wiper liquid (Glycol/Wate | Ethylene glycol, at plant/RER U | kg | 5 | 1 | 5 |
| production | Glider | Axle | Front axle steering | steel, low-alloyed, at plant | kg | 40 | 1.25 | 50 |
| production | Glider | Axle | Rear axle | steel, low-alloyed, at plant | kg | 30 | 1.25 | 37.5 |
| production | Glider | Breaks | Brake shoes, disks, supp | steel, low-alloyed, at plant | kg | 25 | 1.25 | 31.25 |
| production | Glider | Breaks | Brake pressure hoses | # Polyphenylene sulfide, at plant/GLO U | kg | 2 | 1.1 | 2.2 |
| production | Glider | Breaks | Brake oil | Lubricating oil, at plant/RER U | kg | 2 | 1 | 2 |
| production | Glider | Breaks | Brake shoes, supports | Aluminium, production mix, at plant/RER U | kg | 2 | 1.25 | 2.5 |
| production | Glider | Wheels | Rims | reinforcing steel, at plant | kg | 18 | 1.5 | 27 |
| production | Glider | Wheels | Tyres | Synthetic rubber, at plant/RER U | kg | 30 | 1 | 30 |
| production | Glider | Bumper (4 pcs) | Dampers and springs | steel, low-alloyed, at plant | kg | 24 | 1.25 | 30 |
| production | Glider | Air Conditioning | Compressor | reinforcing steel, at plant | kg | 5 | 1.5 | 7.5 |
| production | Glider | Air Conditioning | Compressor | Aluminium, production mix, at plant/RER U | kg | 1 | 1.25 | 1.25 |
| production | Glider | Air Conditioning | Air distribution | polyethylene, HDPE, granulate, at plant | kg | 10 | 1.1 | 11 |
| production | Glider | Air Conditioning | Adapters | Synthetic rubber, at plant/RER U | kg | 1 | 1 | 1 |
| production | Glider | Air Conditioning | Refrigerant R134a Tetraf | Refrigerant R134a, at plant/RER U | kg | 1 | 1 | 1 |
| production | Glider | Cockpit | Cockpit | glass fibre reinforced plastic, polyester, hand-lamina | kg | 20 | 1.1 | 22 |
| production | Glider | Safety (Belts, Airba | Belts airbags | reinforcing steel, at plant | kg | 10 | 1.5 | 15 |
| production | Glider | Safety (Belts, Airba | Belts airbags | Polyethylene terephthalate, granulate, amorphous, | kg | 10 | 1.1 | 11 |
| production | Glider | Interior / Linings | Linings | glass fibre reinforced plastic, polyester, hand-lamina | kg | 57 | 1.1 | 62.7 |
| production | Glider | Interior / Linings | Insulation | glass fibre reinforced plastic, polyester, hand-lamina | kg | 10 | 1.1 | 11 |
| production | Glider | Seats | Seat structure | reinforcing steel, at plant | kg | 30 | 1.5 | 45 |
| production | Glider | Seats | Seat covers | Polyethylene terephthalate, granulate, amorphous, | kg | 30 | 1.1 | 33 |
| production | Glider | Doors | Frames | reinforcing steel, at plant | kg | 55 | 1.5 | 82.5 |
| production | Glider | Doors | Windows side and rear | Flat glass, uncoated, at plant/RER U | kg | 20 | 1 | 20 |
| production | Glider | Electrics / Lights | Lights | Light emitting diode, LED, at plant/GLO U | kg | 0.1 | 1 | 0.1 |
| production | Glider | Electrics / Lights | Cables 3x1.5mm2 65g/m | Cable, connector for computer, without plugs, at pla | kg | 3.25 | 1 | 3.25 |
| production | Glider | Electrics / Lights | El. Motors St. 50% | steel, low-alloyed, at plant | kg | 10 | 1.25 | 12.5 |
| production | Glider | Electrics / Lights | El. Motors Al 30% | Aluminium, production mix, at plant/RER U | kg | 6 | 1.25 | 7.5 |
| production | Glider | Electrics / Lights | El. Motors Cu 20% | copper, at regional storage | kg | 4 | 1 | 4 |
| production | Glider | Electronics | Electronics | Printed wiring board, mixed mounted, unspec., sold | kg | 2 | 1 | 2 |
| production | Glider | Auxiliaries | processing copper | wire drawing, copper | kg | | | 4 |
| production | Glider | Auxiliaries | processing sheet steel | sheet rolling, steel | kg | | | 425 |
| production | Glider | Auxiliaries | | Heat, natural gas, at industrial furnace >100kW/RE | MJ | *5'476* | | 1639 |
| production | Glider | Auxiliaries | | Electricity, medium voltage, production UCTE, at gr | kWh | *1'956* | | 1580 |
| production | Glider | Auxiliaries | | light fuel oil, burned in industrial furnace 1MW, non- | MJ | | | 47 |
| production | Glider | Auxiliaries | | Tap water, at user/RER U | kg | | | 2378 |
| production | Glider | Auxiliaries | | transport, lorry >16t | tkm | | | 39 |
| production | Glider | Auxiliaries | | Transport, freight, rail/RER U | tkm | | | 391 |
| production | Glider | Auxiliaries | | Road vehicle plant/RER/I U | p | | | 2.15E-07 |
| production | Glider | Emissions | emissions to water | COD, Chemical Oxygen Demand | kg | | | 0.142517 |
| production | Glider | Emissions | emissions to water | BOD5, Biological Oxygen Demand | kg | | | 0.019199 |
| production | Glider | Emissions | emissions to water | Phosphate | kg | | | 0.000738 |
| production | Glider | Emissions | emissions to air | NMVOC, non-methane volatile organic compounds, | kg | | | 3.54 |
| production | Glider | Emissions | emissions to air | Heat, waste | MJ | | | 5686 |

## Inventory for the ICE drive-train

**Table S2.** Detailed life cycle inventory for the ICE drive-train

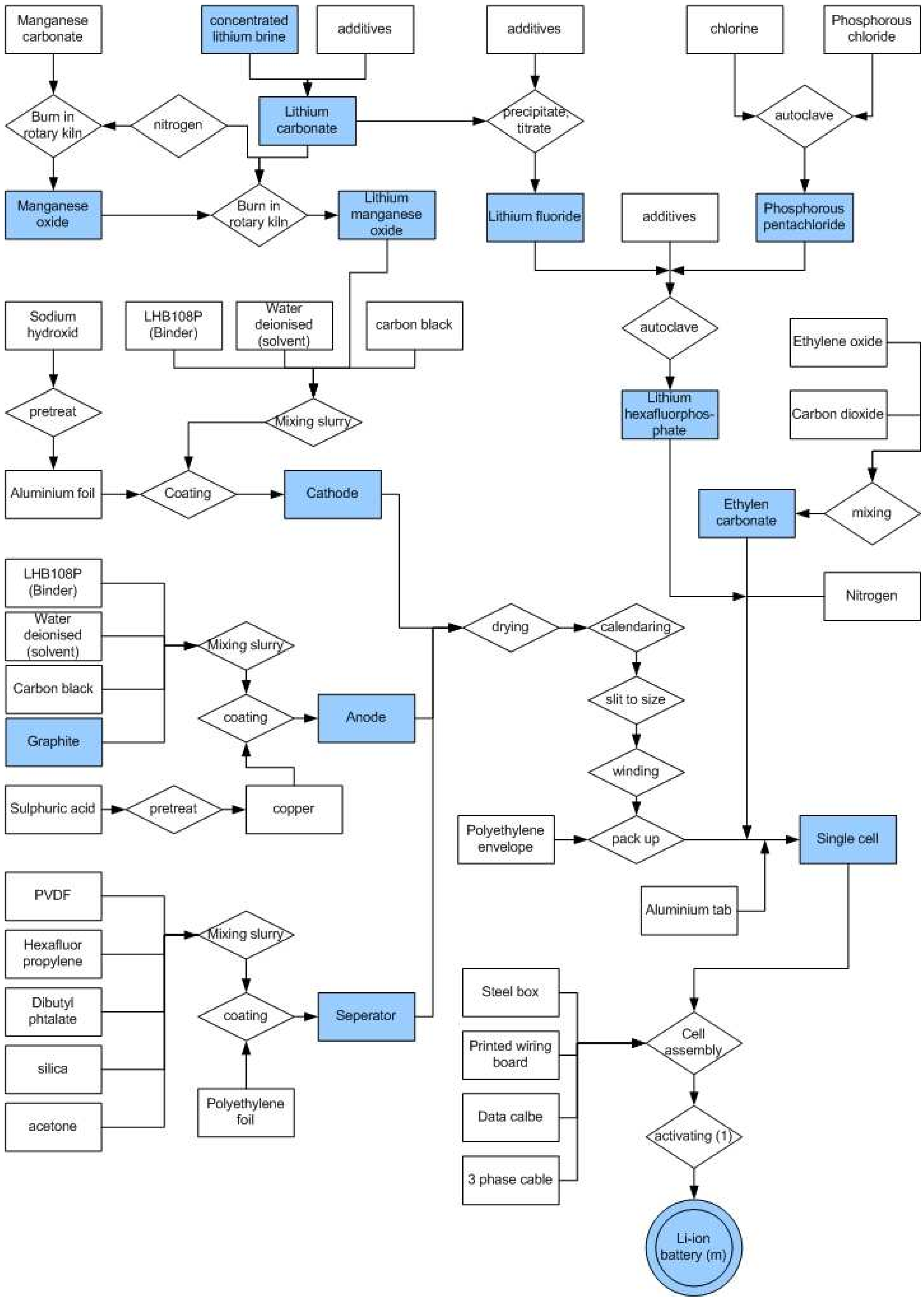
| Phase | Component | Sub1 | Sub2 | Ecoinvent composition | Unit | Amount in vehicle [kg] | Waste factor | Amount in EI [kg] |
|---|---|---|---|---|---|---|---|---|
| production | ICE Drivetrain | Gearbox | Casing (100% sec. AlSi9 | Aluminium, production mix, at plant/RER U | kg | 17 | 1.25 | 21.25 |
| production | ICE Drivetrain | Gearbox | Input shaft with gears | steel, low-alloyed, at plant | kg | 7 | 1.25 | 8.75 |
| production | ICE Drivetrain | Gearbox | Output shaft with gears | steel, low-alloyed, at plant | kg | 8 | 1.25 | 10 |
| production | ICE Drivetrain | Gearbox | Differential | steel, low-alloyed, at plant | kg | 9 | 1.25 | 11.25 |
| production | ICE Drivetrain | Gearbox | Shift parts | steel, low-alloyed, at plant | kg | 1 | 1.25 | 1.25 |
| production | ICE Drivetrain | Gearbox | Others | steel, low-alloyed, at plant | kg | 8 | 1.25 | 10 |
| production | ICE Drivetrain | Gearbox | Clutch | steel, low-alloyed, at plant | kg | 5 | 1.25 | 6.25 |
| production | ICE Drivetrain | Engine | Crankcase | steel, low-alloyed, at plant | kg | 15 | 1.25 | 18.75 |
| production | ICE Drivetrain | Engine | Crankcase | Aluminium, production mix, at plant/RER U | kg | 15 | 1.25 | 18.75 |
| production | ICE Drivetrain | Engine | Crankshaft | steel, low-alloyed, at plant | kg | 8 | 1.25 | 10 |
| production | ICE Drivetrain | Engine | Flywheel | steel, low-alloyed, at plant | kg | 6 | 1.25 | 7.5 |
| production | ICE Drivetrain | Engine | Ring gear | steel, low-alloyed, at plant | kg | 0.5 | 1.25 | 0.625 |
| production | ICE Drivetrain | Engine | Connecting rod ( 4 pc.) | steel, low-alloyed, at plant | kg | 1.5 | 1.25 | 1.875 |
| production | ICE Drivetrain | Engine | Cylinder head | Aluminium, production mix, at plant/RER U | kg | 8 | 1.25 | 10 |
| production | ICE Drivetrain | Engine | Camshaft | steel, low-alloyed, at plant | kg | 2 | 1.25 | 2.5 |
| production | ICE Drivetrain | Engine | Intake valve ( 4 pc.) | steel, low-alloyed, at plant | kg | 0.2 | 1.25 | 0.25 |
| production | ICE Drivetrain | Engine | Hydraulic valve lifter ( 8 p | steel, low-alloyed, at plant | kg | 0.3 | 1.25 | 0.375 |
| production | ICE Drivetrain | Engine | Exhaust valves | steel, low-alloyed, at plant | kg | 0.2 | 1.25 | 0.25 |
| production | ICE Drivetrain | Engine | Pistons (4 pcs) | Aluminium, production mix, at plant/RER U | kg | 0.5 | 1.25 | 0.625 |
| production | ICE Drivetrain | Engine | Intake Manifold | Aluminium, production mix, at plant/RER U | kg | 4 | 1.25 | 5 |
| production | ICE Drivetrain | Engine | injection system | steel, low-alloyed, at plant | kg | 1 | 1.25 | 1.25 |
| production | ICE Drivetrain | Engine | injection system | Aluminium, production mix, at plant/RER U | kg | 1 | 1.25 | 1.25 |
| production | ICE Drivetrain | Engine | injection system | # Polyphenylene sulfide, at plant/GLO U | kg | 2 | 1.1 | 2.2 |
| production | ICE Drivetrain | Engine | Air Filter | # Polyphenylene sulfide, at plant/GLO U | kg | 5 | 1.1 | 5.5 |
| production | ICE Drivetrain | Engine | Others | # Polyphenylene sulfide, at plant/GLO U | kg | 10 | 1.1 | 11 |
| production | ICE Drivetrain | Engine | Others | Lubricating oil, at plant/RER U | kg | 6 | 1 | 6 |
| production | ICE Drivetrain | Cooling System | Water cooler | reinforcing steel, at plant | kg | 2 | 1.5 | 3 |
| production | ICE Drivetrain | Cooling System | Water cooler | Aluminium, production mix, at plant/RER U | kg | 2 | 1.25 | 2.5 |
| production | ICE Drivetrain | Cooling System | Water cooler | polyethylene, HDPE, granulate, at plant | kg | 1 | 1.1 | 1.1 |
| production | ICE Drivetrain | Cooling System | Water cooler | Ethylene glycol, at plant/RER U | kg | 7 | 1 | 7 |
| production | ICE Drivetrain | Cooling System | Ventilator | reinforcing steel, at plant | kg | 1 | 1.5 | 1.5 |
| production | ICE Drivetrain | Cooling System | Ventilator | polyethylene, HDPE, granulate, at plant | kg | 1 | 1.1 | 1.1 |
| production | ICE Drivetrain | Cooling System | Piping | # Polyphenylene sulfide, at plant/GLO U | kg | 4 | 1.1 | 4.4 |
| production | ICE Drivetrain | Cooling System | Piping | Synthetic rubber, at plant/RER U | kg | 2 | 1 | 2 |
| production | ICE Drivetrain | Starting System | Starter motor | steel, low-alloyed, at plant | kg | 4 | 1.25 | 5 |
| production | ICE Drivetrain | Starting System | Starter motor | Aluminium, production mix, at plant/RER U | kg | 1 | 1.25 | 1.25 |
| production | ICE Drivetrain | Starting System | Starter motor | copper, at regional storage | kg | 1 | 1 | 1 |
| production | ICE Drivetrain | Starting System | Alternator | steel, low-alloyed, at plant | kg | 4 | 1.25 | 5 |
| production | ICE Drivetrain | Starting System | Alternator | Aluminium, production mix, at plant/RER U | kg | 1 | 1.25 | 1.25 |
| production | ICE Drivetrain | Starting System | Alternator | copper, at regional storage | kg | 1 | 1 | 1 |
| production | ICE Drivetrain | Starting System | Starter Battery | # Polyphenylene sulfide, at plant/GLO U | kg | 4 | 1.1 | 4.4 |
| production | ICE Drivetrain | Starting System | Starter Battery | lead, at regional storage | kg | 13 | 1 | 13 |
| production | ICE Drivetrain | Starting System | Starter Battery | Sulphuric acid, liquid, at plant/RER U | kg | 1 | 1 | 1 |
| production | ICE Drivetrain | Fuel System | Tubes, fuel pump, fittings | reinforcing steel, at plant | kg | 1 | 1.5 | 1.5 |
| production | ICE Drivetrain | Fuel System | Tank | polyethylene, HDPE, granulate, at plant | kg | 12 | 1.1 | 13.2 |
| production | ICE Drivetrain | Fuel System | Gasoline | Petrol, low-sulphur, at regional storage/RER U | kg | 42 | 1 | 42 |
| production | ICE Drivetrain | Exhaust System | Exhaust Manifold | reinforcing steel, at plant | kg | 8 | 1.5 | 12 |
| production | ICE Drivetrain | Exhaust System | Exhaust Pipes, Muffler | reinforcing steel, at plant | kg | 16 | 1.5 | 24 |
| production | ICE Drivetrain | Exhaust System | Exhaust Pipes, Muffler | Synthetic rubber, at plant/RER U | kg | 1 | 1 | 1 |
| production | ICE Drivetrain | Exhaust System | Catalyzer | steel, low-alloyed, at plant | kg | 5 | 1.5 | 7.5 |
| production | ICE Drivetrain | Exhaust System | Catalyzer | platinum, at regional storage | kg | 0.0016 | 1 | 0.0016 |
| production | ICE Drivetrain | Exhaust System | Catalyzer | palladium, at regional storage | kg | 0.0003 | 1 | 0.0003 |
| production | ICE Drivetrain | Auxiliaries | processing copper | wire drawing, copper | kg | | | 2 |
| production | ICE Drivetrain | Auxiliaries | processing HDPE | Injection moulding/RER U | kg | | | 13 |
| production | ICE Drivetrain | Auxiliaries | | Heat, natural gas, at industrial furnace >100kW/RE | MJ | *1'933* | | 581 |
| production | ICE Drivetrain | Auxiliaries | | Electricity, medium voltage, production UCTE, at gr | kWh | *691* | | 560 |
| production | ICE Drivetrain | Auxiliaries | | light fuel oil, burned in industrial furnace 1MW, non- | MJ | | | 16 |
| production | ICE Drivetrain | Auxiliaries | | Tap water, at user/RER U | kg | | | 842 |
| production | ICE Drivetrain | Auxiliaries | | transport, lorry >16t | tkm | | | 14 |
| production | ICE Drivetrain | Auxiliaries | | Transport, freight, rail/RER U | tkm | | | 139 |
| production | ICE Drivetrain | Auxiliaries | | Road vehicle plant/RER/I U | p | | | 7.61E-08 |
| production | ICE Drivetrain | Emissions | emissions to water | COD, Chemical Oxygen Demand | kg | | | 0.050483 |
| production | ICE Drivetrain | Emissions | emissions to water | BOD5, Biological Oxygen Demand | kg | | | 0.006801 |
| production | ICE Drivetrain | Emissions | emissions to water | Phosphate | kg | | | 0.000262 |
| production | ICE Drivetrain | Emissions | emissions to air | NMVOC, non-methane volatile organic compounds, | kg | | | 1.26 |
| production | ICE Drivetrain | Emissions | emissions to air | Heat, waste | MJ | | | 2014 |

## Inventory for the electric drive-train

**Table S3.** Detailed life cycle inventory for the ICE drive-train

| Phase | Component | Sub1 | Sub2 | Ecoinvent composition | Unit | Amount in vehicle [kg] | Waste factor | Amount in EI [kg] |
|---|---|---|---|---|---|---|---|---|
| production | El. drivetrain | el. motor | magnetic circuit sheet ste | steel, low-alloyed, at plant | kg | 25.00 | 1.5 | 37.5 |
| production | El. drivetrain | el. motor | shaft | steel, low-alloyed, at plant | kg | 2.00 | 1.25 | 2.5 |
| production | El. drivetrain | el. motor | permanent magnet | ferrite, at plant | kg | 1.15 | 1.25 | 1.4375 |
| production | El. drivetrain | el. motor | permanent magnet | neodymium oxide, at plant | kg | 0.42 | 1.25 | 0.525 |
| production | El. drivetrain | el. motor | permanent magnet | boron carbide, at plant | kg | 0.02 | 1.25 | 0.025 |
| production | El. drivetrain | el. motor | windings | copper, at regional storage | kg | 10.00 | 1 | 10 |
| production | El. drivetrain | el. motor | housing | Aluminium, production mix, at plant/RER U | kg | 14.00 | 1.25 | 17.5 |
| production | El. drivetrain | el. motor | housing | # Polyphenylene sulfide, at plant/GLO U | kg | 1.10 | 1.1 | 1.21 |
| production | El. drivetrain | gearbox | differential, transaxle, pa | steel, low-alloyed, at plant | kg | 10.00 | 1.25 | 12.5 |
| production | El. drivetrain | gearbox | housing | Aluminium, production mix, at plant/RER U | kg | 9.00 | 1.25 | 11.25 |
| production | El. drivetrain | controller | electronics | Printed wiring board, mixed mounted, unspec., sold | kg | 2.00 | 1 | 2 |
| production | El. drivetrain | controller | housing | Aluminium, production mix, at plant/RER U | kg | 7.00 | 1.25 | 8.75 |
| production | El. drivetrain | controller | housing | # Polyphenylene sulfide, at plant/GLO U | kg | 0.50 | 1.1 | 0.55 |
| production | El. drivetrain | charger | electronics | Printed wiring board, mixed mounted, unspec., sold | kg | 2.00 | 1 | 2 |
| production | El. drivetrain | charger | housing | Aluminium, production mix, at plant/RER U | kg | 3.70 | 1.25 | 4.625 |
| production | El. drivetrain | charger | housing | # Polyphenylene sulfide, at plant/GLO U | kg | 0.50 | 1.1 | 0.55 |
| production | El. drivetrain | cables | high power 3x16mm2 | cable, three-conductor cable, at plant | kg | 3.12 | 1 | 3.12 |
| production | El. drivetrain | Cooling System | Water cooler | reinforcing steel, at plant | kg | 0.6 | 1.5 | 0.9 |
| production | El. drivetrain | Cooling System | Water cooler | Aluminium, production mix, at plant/RER U | kg | 0.6 | 1.25 | 0.75 |
| production | El. drivetrain | Cooling System | Water cooler | polyethylene, HDPE, granulate, at plant | kg | 0.3 | 1.1 | 0.33 |
| production | El. drivetrain | Cooling System | Water cooler | Ethylene glycol, at plant/RER U | kg | 2.1 | 1 | 2.1 |
| production | El. drivetrain | Cooling System | Ventilator | reinforcing steel, at plant | kg | 0.3 | 1.5 | 0.45 |
| production | El. drivetrain | Cooling System | Ventilator | polyethylene, HDPE, granulate, at plant | kg | 0.3 | 1.1 | 0.33 |
| production | El. drivetrain | Cooling System | Piping | # Polyphenylene sulfide, at plant/GLO U | kg | 1.2 | 1.1 | 1.32 |
| production | El. drivetrain | Cooling System | Piping | Synthetic rubber, at plant/RER U | kg | 0.6 | 1 | 0.6 |
| production | El. drivetrain | Auxiliaries | processing steel | sheet rolling, steel | kg | | | 37.5 |
| production | El. drivetrain | Auxiliaries | processing copper | wire drawing, copper | kg | | | 10 |
| production | El. drivetrain | Auxiliaries | | Heat, natural gas, at industrial furnace >100kW/RE | MJ | *683* | | 252 |
| production | El. drivetrain | Auxiliaries | | Electricity, medium voltage, production UCTE, at gr | kWh | *244* | | 243 |
| production | El. drivetrain | Auxiliaries | | light fuel oil, burned in industrial furnace 1MW, non- | MJ | | | 7 |
| production | El. drivetrain | Auxiliaries | | Tap water, at user/RER U | kg | | | 365 |
| production | El. drivetrain | Auxiliaries | | transport, lorry >16t | tkm | | | 6 |
| production | El. drivetrain | Auxiliaries | | Transport, freight, rail/RER U | tkm | | | 60 |
| production | El. drivetrain | Auxiliaries | | Road vehicle plant/RER/I U | p | | | 3.30E-08 |
| production | El. drivetrain | Emissions | emissions to water | COD, Chemical Oxygen Demand | kg | | | 0.021882 |
| production | El. drivetrain | Emissions | emissions to water | BOD5, Biological Oxygen Demand | kg | | | 0.002948 |
| production | El. drivetrain | Emissions | emissions to water | Phosphate | kg | | | 0.000113 |
| production | El. drivetrain | Emissions | emissions to air | NMVOC, non-methane volatile organic compounds | kg | | | 0.54 |
| production | El. drivetrain | Emissions | emissions to air | Heat, waste | MJ | | | 873 |

**Scheme S2**. Flow Diagram of the production steps from lithium containing brine to the lithium ion battery.




(1) Activating: Charge and discharge cycles of the battery

**Table S4.** Input-output table for the production of concentrated lithium brine.

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | | Process Name | | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Li containing salt from salina lake | ♏ | concentrated lithium brine (6.7 % Li), at plant: Input | | | | Brine Input: 43.8 kg; Li-content: 0.15 % loss: 2% | resource | in ground | | | Lithium, 0.15%in brine, in ground | 6.70E-02 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| diesel fuel | ♏ | | | | | | construction processes | machinery | No | GLO | diesel, burned in building machine | 1.94E-01 | MJ | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,11) |
| | | concentrated lithium brine (6.7 % Li), at plant: Output | ♏ | Concentrated lithium brine (6.7 %Li), at plant | | | chemicals | inorganics | No | GLO | concentrated lithium brine (6.7 % Li), at plant | 1.00E+00 | kg | | | | |

The production of concentrated lithium brine includes inspissations of lithium containing brine by sun energy in the desert of Atacama. The diesel fuel is required for pumping the brine from ground and between different basins as well as for machinery used on the facility [6].

**Table S5.** Input-output table for the production of lithium carbonate ($Li_2CO_3$).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Cate gory | Sub category | Infra struc ture | Loca tion | Modul name in ecoinvent | Mean value | Uni t | Source mean value | Typ e | StDv 95% | General Comment |
| concentrated lithium chloride brine | ε | lithium carbonate, at plant: Input | | | | | chemicals | inorganics | No | GLO | concentrated lithium brine (6.7 % Li), at plant | 9.38E+00 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| Quicklime | ε | | | | | | construction materials | additives | No | CH | quicklime, milled, loose, at plant | 1.76E-01 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| Sulphuric acid | ε | | | | | | chemicals | inorganics | No | RER | sulphuric acid, liquid, at plant | 3.57E-02 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| Hydrochloric acid | ε | | | | | | chemicals | inorganics | No | RER | hydrochloric acid, 30% in H2O, at plant | 5.71E-02 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| Filtering earth | ε | | | | | Proxy for "filtering earth" | construction materials | additives | No | DE | bentonite, at processing | 1.44E-02 | kg | SEIA-CONAMA (2006) | 1 | 1.53 | (2,2,1,3,4,4,4) |
| Alcohol | ε | | | | | Proxy for 7-12 carbon alcohol | chemicals | organics | No | RER | 2-methyl-2-butanol, at plant | 1.19E-03 | kg | SEIA-CONAMA (2006) | 1 | 1.53 | (2,2,1,3,4,4,4) |
| Soda ash | ε | | | | | | chemicals | inorganics | No | RER | soda, powder, at plant | 3.73E+00 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| Organic solvent | ε | | | | | Proxy for a solvent containing "parafines and aromatic compunds" | chemicals | organics | No | GLO | solvents, organic, unspecified, at plant | 4.75E-03 | kg | SEIA-CONAMA (2006) | 1 | 1.53 | (2,2,1,3,4,4,4) |
| Sodium hydroxide | ε | | | | | | chemicals | inorganics | No | RER | sodium hydroxide, 50% in H2O, production mix, at plant | 1.88E-04 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,4) |
| Electricity | ε | | | | | Proxy for "electricity mix Chile" | electricity | supply mix | No | BR | electricity, medium voltage, at grid | 5.60E-04 | kWh | SEIA-CONAMA (2006) | 1 | 1.53 | (2,2,1,3,4,4,2) |
| Natural gas | ε | | | | | use heat: natural gas and heat from liquified gas | natural gas | heating systems | No | RER | natural gas, burned in industrial furnace >100kW | 6.09E+00 | MJ | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,1) |
| Natural gas | ε | | | | | credit: processing of natural gas subtracted, equal to the value of liquified gas | natural gas | fuels | No | RER | natural gas, high pressure, at consumer | -2.00E+00 | MJ | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,1) |
| liquified natural gas | ε | | | | | The plant uses liq. gas. Liq. gas is not available as "heat…" or "burned…" . Thus we balanced more heat from natural gas and made a credit for preparation of natural gas, highg pressure. | natural gas | production | No | JP | natural gas, liquefied, at freight ship | 9.53E-05 | Nm3 | SEIA-CONAMA (2006) | 1 | 1.53 | (2,2,1,3,4,4,11) |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diesel oil | ε | | | | | construction processes | machinery | No | GLO | diesel, burned in building machine | 2.84E-01 | MJ | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,11) |
| Transport lorry 16-32t | ε | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry 16-32t, EURO3 | 2.59E+00 | tkm | SEIA-CONAMA (2006) | 1 | 2.25 | (5,2,1,3,1,4,5) |
| Transport lorry 7.5-16t | ε | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry 7.5-16t, EURO3 | 2.40E-03 | tkm | SEIA-CONAMA (2006) | 1 | 2.25 | (5,2,1,3,1,4,5) |
| Infrastructure, chemical plant | ε | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.24 | (5,2,1,3,1,4,9) |
| | | lithium carbonate, at plant: Output | ε | hazardous waste, underground deposit | | waste management | underground deposit | No | DE | disposal, hazardous waste, 0% water, to underground deposit | 2.05E-04 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,6) |
| | | | ε | non - hazardous waste, residual material landfill | | waste management | residual material landfill | No | CH | disposal, decarbonising waste, 30% water, to residual material landfill | 6.41E+00 | kg | SEIA-CONAMA (2006) | 1 | 1.13 | (2,2,1,3,1,4,6) |
| | | | ε | Waste heat to air | | air | unspecified | | | Heat, waste | 2.02E-03 | MJ | calculated from eletricity input | 1 | 1.24 | (4,2,1,3,1,4,13) |
| | | | ε | Lithium carbonate, at plant | | chemicals | inorganics | No | GLO | lithium carbonate, at plant | 1.00E+00 | kg | | | | |

The concentrated lithium brine is further treated with additives. After removal of boron and a purification step, soda is added for carbonation. As a result, $Li_2CO_3$ precipitates. The salt is then filtered, washed and dried. After this purification step, $Li_2CO_3$ reaches a purity of 99% or higher [7].

**Table S6.** Input-output table for the production of manganese oxide ($Mn_2O_3$).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | | Process Name | | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Manganese carbonate | ε | manganese oxide (Mn2O3), at plant: Input | | | | basic material, no specific quality demand (Kajiya (2005) | metals | extraction | No | GLO | manganese concentrate, at beneficiation | 1.71E+00 | kg | stoichiometrical calculation according to Kajiya (2005) | 1 | 1.58 | (2,4,1,3,4,5,12) |
| Nitrogen | ε | manganese oxide (Mn2O3), at plant: Input | | | | liquid, for inert atmosphere | chemicals | inorganics | No | RER | nitrogen, liquid, at plant | 2.56E+00 | kg | Kajiya (2005) | 1 | 1.24 | (1,4,1,3,1,5,4) |
| Oxygen | ε | manganese oxide (Mn2O3), at plant: Input | | | | liquid, for oxidizing atmosphere | chemicals | inorganics | No | RER | oxygen, liquid, at plant | 5.37E-01 | kg | Kajiya (2005) | 1 | 1.24 | (1,4,1,3,1,5,4) |
| Electricity | ε | manganese oxide (Mn2O3), at plant: Input | | | | mechanical drive of the rotary kiln | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 5.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | manganese oxide (Mn2O3), at plant: Input | | | | Heat | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 4.13E+00 | MJ | calculated according to stoichiometry including enthalpy of reaction | 1 | 1.40 | (4,4,1,3,3,5,1) |
| Transport lorry | ε | manganese oxide (Mn2O3), at plant: Input | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 4.81E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | manganese oxide (Mn2O3), at plant: Input | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 2.20E+00 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Infrastructure, chemical plant | ε | manganese oxide (Mn2O3), at plant: Input | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| | | manganese oxide (Mn2O3), at plant: Output | ε | manganese carbonate | | 85 % manganese conversion from MnCO3 to Mn2O3, 15% loss | waste management | inert material landfill | No | CH | disposal, inert waste, 5% water, to inert material landfill | 2.57E-01 | kg | Kajiya (2005) | 1 | 1.33 | (2,4,1,1,3,5,6) |
| | | manganese oxide (Mn2O3), at plant: Output | ε | waste heat to air | | | air | unspecified | | | Heat, waste | 1.80E-02 | MJ | calculated from eletricity input | 1 | 1.32 | (4,4,1,3,1,5,13) |
| | | manganese oxide (Mn2O3), at plant: Output | ε | CO2 | | amount of CO2 that results from the stoichiometry | air | unspecified | | | Carbon dioxide, fossil | 2.79E-01 | kg | stoichiometrical calculation according to Kajiya (2005) | 1 | 1.32 | (4,4,1,3,1,5,14) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ε | Equal amount of CO as CO2 (stoichiometry), conversion of CO to CO2, | Assumption: CO (stoichiometry) is redirected to the rotary kiln and oxidised to CO2 | air | unspecified | | | Carbon dioxide, fossil | 2.79E-01 | kg | calculated, conversion of CO to CO2 | 1 | 1.32 | (4,4,1,3,1,5,14) |
| | ε | CO | Assumption: CO to the atmosphere is equal to the CO after thermal post-combustion (<20mgC/Nm3) | air | unspecified | | | Carbon monoxide, fossil | 4.67E-05 | kg | stoichiometrical calculation according to Kajiya (2005) | 1 | 5.38 | (4,4,1,3,4,5,17) |
| | ε | Mn2O3 | | chemicals | inorganics | No | CN | manganese oxide (Mn2O3), at plant | 1.00E+00 | kg | | | | |

$Mn_2O_3$ is produced by a two stage roasting whereby manganese carbonate is roasted in an atmosphere low in oxygen content, followed by roasting in an atmosphere high in oxygen content [8]. According to Kajiya [8], the process does not require any specific quality to the basic raw material (manganese carbonate). Applying this process, $Mn_2O_3$ reaches battery grade quality. Thermal heat input is calculated from specific heat energy (heating up to 500°C) of manganese carbonate, nitrogen and oxygen and the reaction of enthalpy (stoichiometrical consideration) from the conversion of manganese carbonate to manganese oxide [9]. We assumed thermal post combustion for the carbon monoxide (CO- emission < 20 ppm). The conversion factor for manganese carbonate is 85%.

**Table S7.** Input-output table for the production of lithium manganese oxide ($LiMn_2O_4$).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Cate gory | Sub category | Infra struc ture | Loca tion | Modul name in ecoinvent | Mean value | Uni t | Source mean value | Typ e | StDv 95% | General Comment |
| Manganese oxide | ε | lithium manganese oxide, at plant: Input | | | | manganese component | chemicals | inorganics | No | CN | manganese oxide (Mn2O3), at plant | 9.18E-01 | kg | stoichiometrical calculation according to Heil (2003) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Lithium carbonate | ε | | | | | lithium component | chemicals | inorganics | No | GLO | lithium carbonate, at plant | 2.15E-01 | kg | stoichiometrical calculation according to Heil (2003) | 1 | 1.25 | (2,4,2,3,1,5,12) |
| Oxygen | ε | | | | | liquid, for oxidising atmosphere | chemicals | inorganics | No | RER | oxygen, liquid, at plant | 7.15E-01 | kg | according to Heil (2003) | 1 | 1.24 | (1,4,2,3,1,5,4) |
| Nitrogen | ε | | | | | liquid, for inert atmosphere | chemicals | inorganics | No | RER | nitrogen, liquid, at plant | 7.86E-01 | kg | according to Heil (2003) | 1 | 1.24 | (1,4,2,3,1,5,4) |
| Water | ε | | | | | for suspension: 3 parts water, 1 part Mn2O3 and Li2CO3 powder | water supply | production | No | CH | water, deionised, at plant | 3.40E+00 | kg | according to Heil (2003) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Electricity | ε | | | | | mechanical drive of the rotary kiln | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 5.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | | furnace for rotary kiln | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 1.53E+01 | MJ | calculated according to stoichiometry including enthalpy of reaction | 1 | 1.33 | (4,4,2,3,1,5,1) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 5.64E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 3.23E+00 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Infrastructure, chemical plant | ε | | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lithium manganese oxide, at plant: Output | ε | Manganese oxide | 95 % manganese conversion, 5% loss according to ecoinvent guidelines | waste management | inert material landfill | No | CH | disposal, inert waste, 5% water, to inert material landfill | 4.59E-02 | kg | 5% loss, according to ecoinvent assumption for missing information | 1 | 1.25 | (2,4,2,3,1,5,6) |
| | ε | Lithium carbonate | 95 % manganese conversion, 5% loss according to ecoinvent guidelines | waste management | inert material landfill | No | CH | disposal, inert waste, 5% water, to inert material landfill | 1.07E-02 | kg | 5% loss, according to ecoinvent assumption for missing information | 1 | 1.25 | (2,4,2,3,1,5,6) |
| | ε | Waste heat to air | | air | unspecified | | | Heat, waste | 1.80E-02 | MJ | calculated from eletricity input | 1 | 1.33 | (4,4,2,3,1,5,13) |
| | ε | Waste water to air | evaporated water | air | high population density | | | Water | 3.40E+00 | kg | Heil (2003) | 1 | 1.33 | (4,4,2,3,1,5,4) |
| | ε | CO2 | amount of CO2 that results from the stoichiometry | air | unspecified | | | Carbon dioxide, fossil | 1.28E-01 | kg | stoichiometrical calculation according to Heil (2003) | 1 | 1.33 | (4,4,2,3,1,5,14) |
| | ε | Lithium manganese oxide | | chemicals | inorganics | No | GLO | lithium manganese oxide, at plant | 1.00E+00 | kg | | | | |

The production of $LiMn_2O_4$ contains several roasting stages of $Li_2CO_3$ and $Mn_2O_3$ in a rotary kiln [10]. During the different stages, the atmosphere in the rotary kiln changes from inert (addition of $N_2$) to oxidizing (addition of $O_2$) condition. The powder is then suspended with water followed by spray drying (evaporation of the water). Thermal heat input is calculated from specific heat energy (heating up to 750°C) of $Li_2CO_3$, $Mn_2O_3$, $N_2$ and $O_2$ and the reaction of enthalpy (stoichiometrical consideration) from the conversion $Li_2CO_3$ and $Mn_2O_3$ [9] to $LiMn_2O_4$ [11]. $CO_2$ emissions are calculated considering stoichiometrical considerations.

**Table S8.** Input-output table for the production of phosphorous pentachloride ($PCl_5$).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Phosphorus trichloride | ε | phosphorous pentachloride, at plant: Input | | | | calculated conversion: 93.9% | chemicals | inorganics | No | RER | phosphorous chloride, at plant | 7.03E-01 | kg | stoichiometrical calculation according to Münster (1981) | 1 | 1.58 | (2,4,5,3,1,5,4) |
| Chlorine | ε | | | | | calculated conversion: 93.9% | chemicals | inorganics | No | RER | chlorine, liquid, production mix, at plant | 3.63E-01 | kg | stoichiometrical calculation according to Münster (1981) | 1 | 1.58 | (2,4,5,3,1,5,4) |
| Electricity | ε | | | | | mechanical drive for stirring and pumping | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | | furnace of the reactor | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 8.67E-02 | MJ | calculated according to stoichiometry, specific heat and enthalpy of reaction according to Münster (1981) | 1 | 1.64 | (4,4,5,3,1,5,1) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 1.07E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 4.58E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Infrastructure, chemical plant | ε | | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| | | phosphorous pentachloride, at plant: Output | ε | Phosphorus trichloride | | Conversion: 93.8% | air | high population density | | | Phosphorus trichloride | 4.32E-02 | kg | Münster (1981) | 1 | 2.29 | (2,4,5,3,1,5,23) |
| | | | ε | Chlorine | | Conversion: 93.8% | air | high population density | | | Chlorine | 2.23E-02 | kg | Münster (1981) | 1 | 1.58 | (2,4,5,3,1,5,24) |
| | | | ε | Waste heat to air | | | air | unspecified | | | Heat, waste | 7.20E-03 | MJ | calculated from eletricity input | 1 | 1.64 | (4,4,5,3,1,5,13) |
| | | | ε | Phosphorus pentachloride | | | chemicals | inorganics | No | CN | phosphorous pentachloride, at plant | 1.00E+00 | kg | | | | |

$PCl_5$ is manufactured from chlorine and phosphorus trichloride in the presence of molten $PCl_5$ [12]. The process can be carried out such that the reaction product flows out from the reactor continuously as a melt. Thermal heat input is calculated from specific heat energy (heating up to 180°C) for phosphorus chloride and chlorine [9]. The conversion factor is 93.8%.

**Table S9.** Input-output table for the production of lithium fluoride (LiF).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | | Process Name | | Output | | Remarks | Cate gory | Sub category | Infra struc ture | Loca tion | Modul name in ecoinvent | Mean value | Uni t | Source mean value | Typ e | StDv 95% | General Comment |
| lithium carbonate | ε | lithium fluoride, at plant: Input | | | | 40% hydrogen fluoride in 60% water | chemicals | inorganics | No | GLO | lithium carbonate, at plant | 1.49E+00 | kg | stoichiometrical calculation according to Friedrich (1999) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| hydrogen fluoride | ε | | | | | 40% hydrogen fluoride in 60% water | chemicals | inorganics | No | GLO | hydrogen fluoride, at plant | 8.06E-01 | Kg | stoichiometrical calculation according to Friedrich (1999) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Ammoniac | ε | | | | | Assumption Gregor Wernet: 5% of protons have to be neutralised with NH3 | chemicals | inorganics | No | RER | ammonia, liquid, at regional storehouse | 3.28E-02 | kg | Interview with G. Wernet, J. Sutter, ETH Zürich | 1 | 1.33 | (4,4,2,3,1,5,4) |
| water | ε | | | | | 1.) 60% water in 40% hydrogen fluoride, 2.) 1 liter from washing LiF | water supply | production | No | CH | water, deionised, at plant | 2.21E+00 | kg | Friedrich (1999) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Process heat | ε | | | | | Assumption: water content of LiF according to Hansen (1985) | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 1.21E+00 | MJ | Hansen (1985) | 1 | 1.33 | (4,4,2,3,1,5,1) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 2.33E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 1.40E+00 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Infrastructure, chemical plant | ε | | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| | | de , at | ε | wastewater | | water from HF solution | waste management | wastewater treatment | No | CH | treatment, sewage, to wastewater | 2.21E-03 | m3 | Friedrich (1999) | 1 | 1.33 | (4,4,2,3,1,5,6) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | treatment, class 1 | | | | | | |
| | ε | wastewater | from chemical reaction | waste management | wastewater treatment | No | CH | treatment, sewage, to wastewater treatment, class 1 | 3.63E-04 | m3 | stoichiometrical calculation according to Friedrich (1999) | 1 | 1.33 | (4,4,2,3,1,5,6) |
| | ε | water | from washing the LiF, Assumption: 1 Liter water to wash 1 kg LIF | waste management | wastewater treatment | No | CH | treatment, sewage, to wastewater treatment, class 1 | 1.00E-03 | m3 | Friedrich (1999) | 1 | 1.58 | (5,4,2,3,1,5,6) |
| | ε | lithium carbonate | Li2CO3, 4.5% of input | | | | | | 6.70E-02 | kg | Friedrich (1999) | 1 | 1.25 | (2,4,2,3,1,5,6) |
| | ε | hydrogen fluoride | HF, 4.5% of input | air | high population density | | | Hydrogen fluoride | 3.63E-02 | kg | Friedrich (1999) | 1 | 1.25 | (2,4,2,3,1,5,6) |
| | ε | Ammonium ion | mass calculated, based on 5% NH3 input | water | unspecified | | | Ammonium, ion | 3.47E-02 | kg | Friedrich (1999) | 1 | 1.58 | (2,4,2,3,1,5,33) |
| | ε | carbon dioxide | from chemical reaction | air | unspecified | | | Carbon dioxide, fossil | 8.86E-01 | kg | stoichiometrical calculation according to Friedrich (1999) | 1 | 1.33 | (4,4,2,3,1,5,24) |
| | ε | lithium fluoride | | chemicals | inorganics | No | CN | lithium fluoride, at plant | 1.00E+00 | kg | | | | |

$Li_2CO_3$ reacts with hydrogen fluoride at room temperature to LiF. The filtrate is titrated (pH 7.5) with ammoniac, washed with water and dried. The conversion factor regarding Lithium is 95.5% [13].

**Table S10.** Input-output table for the production of Lithium hexafluorophosphate ($LiPF_6$).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Lithium fluoride | ε | lithium hexafluorophosphate, at plant: Input | | | | 86.7% conversion of lithium | chemicals | inorganics | No | CN | lithium fluoride, at plant | 1.97E-01 | kg | stoichiometrical calculation according to Belt (1998) | 1 | 1.27 | (2,4,3,3,1,5,4) |
| Phosphorous pentachloride | ε | | | | | 86.7% conversion of phosphorous chlorid, 25% overspill in relation to LiF | chemicals | inorganics | No | CN | phosphorous pentachloride, at plant | 1.98E+00 | kg | stoichiometrical calculation according to Belt (1998) | 1 | 1.27 | (2,4,3,3,1,5,4) |
| Hydrogen fluoride | ε | | | | | Overspill: 532% | chemicals | inorganics | No | GLO | hydrogen fluoride, at plant | 4.04E+00 | kg | stoichiometrical calculation according to Belt (1998) | 1 | 1.27 | (2,4,3,3,1,5,4) |
| Nitrogen | ε | | | | | Inert atmosphere | chemicals | inorganics | No | RER | nitrogen, liquid, at plant | 1.25E-03 | kg | Assumption from G. Wernet, J. Sutter | 1 | 1.33 | (4,4,2,3,1,5,4) |
| Ca(OH)2 | ε | | | | | Neutralisation and disposal of HF | construction materials | binder | No | CH | lime, hydrated, packed, at plant | 7.44E+00 | kg | Assumption from G. Wernet, J. Sutter, ETH | 1 | 2.39 | (4,5,5,5,5,5,4) |
| Electricity | ε | | | | | Assumption:heat pump with coefficient of performance =1.5 | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 5.39E-01 | kWh | Calculation of cooling (including enthalpy of reaction) according to Belt (1985) | 1 | 1.27 | (2,4,3,3,1,5,2) |
| Electricity | ε | | | | | for pumps, stirring, milling of LiPF6, etc. | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 1.37E+00 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 8.19E+00 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Infrastructure, chemical plant | ε | | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lithium hexafluorophosphate, at plant: Output | ε | disposal of KF and KCL | disposal of salts from neutralisation process, proxy | waste management | inert material landfill | No | CH | disposal, limestone residue, 5% water, to inert material landfill | 8.61E+00 | kg | calculated | 1 | 2.12 | (4,4,3,3,5,5,6) |
| | ε | wastewater | water from reaction for neutralisation of HF and HCl | waste management | wastewater treatment | No | CH | treatment, sewage, to wastewater treatment, class 1 | 3.61E-03 | m3 | calculated | 1 | 2.12 | (4,4,3,3,5,5,6) |
| | ε | LiF | LiF to recycling | | | | | | 2.62E-02 | kg | stoichiometrical calculation according to Belt (1998) | 2 | 1.56 | |
| | ε | Phosphorous trichliride | PCl3 13.3% of input, proxy for PCl5 | air | high population density | | | Phosphorus trichloride | 2.63E-01 | kg | Belt (1998) | 1 | 1.60 | (2,4,3,3,1,5,31) |
| | ε | waste heat to air | heat pump and laboratory apparatus | air | unspecified | | | Heat, waste | 1.95E+00 | MJ | calculated from electricity input | 1 | 1.34 | (4,4,3,3,1,5,13) |
| | ε | Lithium hexafluororphosphate | | chemicals | inorganics | No | CN | lithium hexafluorophosphate, at plant | 1.00E+00 | kg | | | | |

The production of $LiPF_6$ requires a reaction of $PCl_5$, LiF and hydrogen fluoride (HF), wherein $PCl_5$ and LiF are combined, cooled (to – 78°C) and the HF is added in excess for complete chlorine-fluorine exchange in the $PCl_5$. Electric energy input is calculated for a heat pump with an assumed coefficient of performance of 1.5 [14]. The reaction in the autoclave occurs in an inert nitrogen atmosphere. The conversion factor regarding LiF is 87% [15].

**Table S11.** Input-output table for the production of ethylene carbonate ($C_3H_4O_3$).

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | | Process Name | | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Ethylene oxide | ε | ethylene carbonate, at plant: Input | | | | 99.95% conversion of ethylene oxide to ethylene carbonate | chemicals | organics | No | RER | ethylene oxide, at plant | 5.01E-01 | kg | stoichiometrical calculation according to Birnbach (2003) | 1 | 1.25 | (2,4,2,3,1,5,3) |
| Carbon dioxide | ε | | | | | 1% CO2 excess | chemicals | inorganics | No | RER | carbon dioxide liquid, at plant | 5.05E-01 | kg | stoichiometrical calculation according to Birnbach (2003) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Infrastructure: chemical plant | ε | | | | | Ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| Electricity | ε | | | | | mechanical drive of labor mixer and pumps | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | | furnace of the reactor | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 1.43E-01 | MJ | calculated according to stoichiometry, specific heat and enthalpy of reaction according to Birnbach (2003) | 1 | 1.33 | (4,4,2,3,1,5,1) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 1.01E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 3.51E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| | | ethylene carbonate, at plant: Output | ε | catalyst | | according to ecoinvent ethylenoxide production (0.5 kg / 1000 kg product) | waste management | residual material landfill | No | CH | disposal, catalyst base Eth.oxide prod., 0% water, to residual material landfill | 5.00E-03 | kg | according to ecoinvent ethylenoxide production (0.5 kg / 1000 kg product) | 1 | 1.33 | (2,4,2,3,3,5,6) |
| | | | ε | ethylene oxide | | loss: 0.05% | air | unspecified | | | Ethylene oxide | 2.50E-04 | kg | Birnbach (2003) | 1 | 2.07 | (2,4,2,3,1,5,23) |
| | | | ε | carbon dioxide | | loss: 0.05% from conversion, 1% excess | air | unspecified | | | Carbon dioxide, fossil | 5.30E-03 | kg | Birnbach (2003) | 1 | 1.25 | (2,4,2,3,1,5,24) |
| | | | ε | Waste heat to air | | | air | unspecified | | | Heat, waste | 7.20E-03 | MJ | calculated from eletricity input | 1 | 1.33 | (4,4,2,3,1,5,13) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ε | Ethylene carbonate | | chemicals | organics | No | CN | ethylene carbonate, at plant | 1.00E+00 | kg | | | | |

Ethylene oxide and $CO_2$ react with the aid of a catalyst under adiabatic conditions to $C_3H_4O_3$. Thermal heat input is calculated from specific heat energy (heating up to 126°C) for ethylene oxide and $CO_2$ [9]. The conversion factor regarding ethylene oxide is 99.95% [16].

**Table S12.** Input-output table for the production of battery grade graphite

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Cate gory | Sub category | Infra struc ture | Loca tion | Modul name in ecoinvent | Mean value | Uni t | Source mean value | Typ e | StDv 95% | General Comment |
| water | ε | graphite, battery grade, at plant: Input | | | | | resource | in water | | | Water, well, in ground | 2.93E-05 | m3 | Ecoinvent dataset "graphite, at plant* | 1 | 1.33 | (2,4,1,3,3,5,4) |
| graphite containing rock | ε | | | | | | resource | in ground | | | Metamorphous rock, graphite containing, in ground | 1.05E+00 | kg | Ecoinvent dataset "graphite, at plant* | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Land use | ε | | | | | | resource | land | | | Occupation, mineral extraction site | 8.48E-05 | m2a | Ecoinvent dataset "graphite, at plant* | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Land transformation | ε | | | | | | resource | land | | | Transformation, to mineral extraction site | 6.52E-06 | m2 | Ecoinvent dataset "graphite, at plant* | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Land transformation | ε | | | | | | resource | land | | | Transformation, from forest | 6.52E-06 | m2 | Ecoinvent dataset "graphite, at plant* | 1 | 1.16 | (1,4,1,3,1,4,4) |
| Recultivation, limestone mine | ε | | | | | | construction materials | additives | No | CH | recultivation, limestone mine | 6.52E-06 | m2 | Ecoinvent dataset "graphite, at plant* | 1 | 1.16 | (1,4,1,3,1,4,4) |
| Mine, limestone | ε | | | | | | construction materials | additives | Yes | CH | mine, limestone | 5.25E-11 | unit | Ecoinvent dataset "graphite, at plant* | 1 | 1.32 | (4,4,1,3,1,5,4) |
| Blasting | ε | | | | | | construction processes | civil engineering | No | RER | blasting | 7.73E-05 | kg | Ecoinvent dataset "graphite, at plant* | 1 | 2.11 | (4,4,1,3,1,5,5) |
| Heat | ε | | | | | | oil | heating systems | No | RER | heat, light fuel oil, at industrial furnace 1MW | 8.98E-02 | MJ | Ecoinvent dataset "graphite, at plant* | 1 | 3.36 | (5,5,2,3,3,5,9) |
| Light fuel oil | ε | | | | | | oil | heating systems | No | CH | light fuel oil, burned in boiler 100kW, non-modulating | 3.59E-03 | MJ | Ecoinvent dataset "graphite, at plant* | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Diesel | ε | | | | | | construction processes | machinery | No | GLO | diesel, burned in building machine | 1.80E-02 | MJ | Ecoinvent dataset "graphite, at plant* | 1 | 1.32 | (4,4,1,3,1,5,1) |
| Industrial machine | ε | | | | | | construction processes | machinery | Yes | RER | industrial machine, heavy, unspecified, at plant | 2.31E-04 | kg | Ecoinvent dataset "graphite, at plant* | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Conveyer belt | ε | | | | | | construction processes | machinery | Yes | RER | conveyor belt, at plant | 2.78E-08 | m | Ecoinvent dataset "graphite, at plant* | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Electricity | | | | | | | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 1.03E+00 | kWh | calculated according to www.timcal.com and Ecoinvent dataset "graphite, at plant* | 1 | 1.53 | (2,2,1,3,4,4,2) |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hard coal coke | | | | | hard coal | fuels | No | GLO | hard coal coke, at plant | 4.00E+01 | MJ | calculated according to www.timcal.com | 1 | 1.53 | (2,2,1,3,4,4,1) |
| | graphite, battery grade, at plant: Output | ε | Particulates < 2.5um | | air | unspecified | | | Particulates, < 2.5 um | 8.87E-06 | kg | Ecoinvent dataset "graphite, at plant* | 1 | 1.58 | (5,4,1,3,1,5,6) |
| | | ε | Particulates > 2.5 um < 10 um | | air | unspecified | | | Particulates, > 10 um | 4.78E-05 | kg | Ecoinvent dataset "graphite, at plant* | 1 | 1.84 | (5,4,1,3,1,5,33) |
| | | ε | Particulates > 10 um | | air | unspecified | | | Particulates, > 2.5 um, and < 10um | 1.21E-04 | kg | Ecoinvent dataset "graphite, at plant* | 1 | 1.32 | (4,4,1,3,1,5,13) |
| | | ε | Waste heat to air | | air | unspecified | | | Heat, waste | 3.72E+00 | MJ | calculated from eletricity input | 1 | 1.63 | (4,4,1,3,1,5,31) |
| | | ε | Anode, lithium-ion battery | | chemicals | inorganics | No | CN | graphite, battery grade, at plant | 1.00E+00 | kg | | | | |

This dataset is based on the ecoinvent dataset “graphite, at plant”. Battery grade graphite is much more energy intense than industrial graphite. Hence, aditional inputs (coke and electricity) are added to the ecoinvent original graphite dataset. The purity of synthetic graphite is >99.9%.

**Table S13.** Input-output table for the production of a cathode.

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Latex | ε | Cathode, lithium-ion battery, lithium manganese oxide, at plant: Input | | | | Binder, (Styrene-butadiene) | chemicals | organics | No | RER | latex, at plant | 9.89E-03 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Water | ε | | | | | Solvent for the binder | water supply | production | No | CH | water, deionised, at plant | 2.00E-01 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Lithium manganese oxide | ε | | | | | Active material, LiMn2O4 | chemicals | inorganics | No | GLO | lithium manganese oxide, at plant | 6.23E-01 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Carbon black | ε | | | | | Conductive carbon | chemicals | inorganics | No | GLO | carbon black, at plant | 2.64E-02 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Aluminium foil | ε | | | | | Aluminium for the collector | metals | extraction | No | RER | aluminium, production mix, wrought alloy, at plant | 3.93E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.16 | (1,4,1,3,1,4,4) |
| Aluminium foil rolling | ε | | | | | Sheet in the range of 0.2 to 6 mm | metals | processing | No | RER | sheet rolling, aluminium | 3.93E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.16 | (1,4,1,3,1,4,4) |
| Sodium hydroxide | ε | | | | | NaOH, 50 % water, value per m2 from powder coating, aluminium sheet, | chemicals | inorganics | No | RER | sodium hydroxide, 50% in H2O, production mix, at plant | 1.30E-01 | kg | equivalent amount of protons as in "cathode li-ion battery" OH- for treatment of alu foil | 1 | 1.32 | (4,4,1,3,1,5,4) |
| Sulfuric acid | ε | | | | | H2SO4 from the process "Anode,, lithium-ion battery" to neutralise NaOH | | | | | | 8.08E-02 | kg | equivalent amount of OH- to neutralise H2SO4 | 1 | 1.32 | (4,4,1,3,1,5,4) |
| Infrastructure, chemical plant | ε | | | | | Ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| Electricity | ε | | | | | Mechanical drive for pumping slurry, coating, coiling, cutting | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | | Evaporating water, heating active amterial, alu-foil, binder, solvent, black carbon | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 6.46E-01 | MJ | calculated from specific heat of the base materials | 1 | 1.32 | (4,4,1,3,1,5,1) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 1.26E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 7.58E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cathode, lithium-ion battery, lithium manganese oxide, at plant: Output | ε | Disposal coated cathode | 5% loss, according to ecoinvent assumption for missing information, included waste from slitting the coils, copper to recycling | waste management | municipal incineration | No | CH | disposal, residues, shredder fraction from manual dismantling, in MSWI | 5.26E-02 | kg | 5% loss, according to ecoinvent assumption for missing information | 1 | 1.58 | (5,4,1,3,1,5,6) |
| | ε | Waste water | Assumption: NaOH is neutralized with H2SO4, only 50% disposed, the other 50% is disposed in the dataset Cathode, lithoim-iom battery" | waste management | wastewater treatment | No | CH | treatment, sewage, to wastewater treatment, class 3 | 1.05E-04 | m3 | equal to the amount of NaOH input | 1 | 1.84 | (5,4,1,3,1,5,33) |
| | ε | Waste heat to air | Heat and electric power | air | unspecified | | | Heat, waste | 7.20E-03 | MJ | calculated from eletricity input | 1 | 1.32 | (4,4,1,3,1,5,13) |
| | ε | Waste water | Solvent water evaporated from the slurry | air | unspecified | | | Water | 2.00E-01 | kg | calculated from NaOH input | 1 | 1.63 | (4,4,1,3,1,5,31) |
| | ε | Cathode, lithium-ion battery | | electronics | component | No | CN | Cathode, lithium-ion battery, lithium manganese oxide, at plant | 1.00E+00 | kg | | | | |

The production of the cathode requires the mixture of the components (binder and solvent, $LiMn_2O_4$, black carbon) in a ball mill to a slurry [17, 18], followed by coating the collector (with soda lye pre-treated aluminium foil) with the slurry. The binder (modified styrene butadiene copolymer [19]) is water soluble and has the advantage that no organic solvent is needed. Thermal heat energy is used to heat up the slurry to130°C and to evaporate water and to dry the coated cathode in a dry channel ($H_2O$ content < 20ppm) [20].

**Table S14.** Input-output table for the production of an anode.

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Latex | ε | Anode, lithium-ion battery, graphite, at plant: Input | | | | Binder, (Styrene-butadiene) | chemicals | organics | No | RER | latex, at plant | 1.85E-02 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Water | ε | | | | | Solvent for the binder | water supply | production | No | CH | water, deionised, at plant | 4.24E-01 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Graphite | ε | | | | | Active material | chemicals | inorganics | No | CN | graphite, battery grade, at plant | 4.94E-01 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| Carbon black | ε | | | | | Conductive carbon | chemicals | inorganics | No | GLO | carbon black, at plant | 1.59E-02 | kg | advanced battery materials | 1 | 1.33 | (2,4,1,3,3,5,4) |
| copper | ε | | | | | Copper for the collector | metals | extraction | No | RER | copper, at regional storage | 5.24E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.16 | (1,4,1,3,1,4,4) |
| Copper foil | ε | | | | | Sheet in the range of 0.2 to 6 mm | metals | processing | No | RER | sheet rolling, copper | 5.24E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.16 | (1,4,1,3,1,4,4) |
| Sulfuric acid | ε | | | | | Sulfuric acid, equivalent amount of protons as in "cathode li-ion battery" OH- for treatment of alu foil | chemicals | inorganics | No | RER | sulphuric acid, liquid, at plant | 8.08E-02 | kg | equivalent amount of protons as in "cathode li-ion battery" OH- for treatment of alu foil | 1 | 1.32 | (4,4,1,3,1,5,4) |
| Sodium hydroxide | ε | | | | | NaOH from the process "Cathode, lithium-ion battery" to neutralise H2SO4 | | | | | | 1.32E-01 | kg | equivalent amount of OH- to neutralise H2SO4 | 1 | 2.11 | (4,4,1,3,1,5,5) |
| Infrastructure, chemical plant | ε | | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| Electricity | ε | | | | | Mechanical drive for pumping slurry, coating, coiling, cutting | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | | Evaporating water, heating active amterial, alu-foil, binder, solvent, black carbon | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 1.22E+00 | MJ | calculated from specific heat of the base materials | 1 | 1.32 | (4,4,1,3,1,5,1) |
| Transport lorry | ε | | | | | According to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 1.13E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | According to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 4.70E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| | | batter y, graphi | ε | coated copper to copper recycling | | 5% loss, according to ecoinvent assumption for missing information, included waste from slitting the coils, | | | | | | 5.26E-02 | kg | 5% loss, according to ecoinvent assumption for missing | 1 | 1.58 | (5,4,1,3,1,5,6) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | copper to recycling | | | | | | | | information | | | |
| | ε | Waste water | Assumption:NaOH is neutralized with H2SO4, only 50% disposed, the other 50% is disposed in the dataset Cathode, lithoim-iom battery" | waste management | wastewater treatment | No | CH | treatment, sewage, to wastewater treatment, class 3 | 1.06E-04 | m3 | equal to the amount of NaOH input | 1 | 1.84 | (5,4,1,3,1,5,33) |
| | ε | Waste heat to air | Heat and electric power | air | unspecified | | | Heat, waste | 7.20E-03 | MJ | calculated from eletricity input | 1 | 1.32 | (4,4,1,3,1,5,13) |
| | ε | Waste water | Solvent water evaporated from the slurry | air | unspecified | | | Water | 4.24E-01 | kg | calculated from NaOH input | 1 | 1.63 | (4,4,1,3,1,5,31) |
| | ε | Anode, lithium-ion battery | | electronics | component | No | CN | Anode, lithium-ion battery, graphite, at plant | 1.00E+00 | kg | | | | |

Basically the same process is applied for the production of the anode. Instead of $LiMn_2O_4$, graphite is used for the anode. The collector is a copper foil, pre-treated with sulphuric acid.

**Table S15.** Input-output table for the production of a separator.

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Polyethylene fleese | ε | Separator, lithium-ion battery, at plant: Input | | | | foil, carrier for slurry | plastics | polymers | No | RER | fleece, polyethylene, at plant | 3.51E-01 | kg | Assumption: Polytehylene foil is 33% of total weight (3 layers with equal weight) | 1 | 1.64 | (5,4,2,3,3,5,4) |
| PVDF | ε | | | | | PVF is a proxy für PVDF | chemicals | organics | No | US | polyvinylfluoride, at plant | 1.92E-01 | kg | Hyung-Gon (2002) | 1 | 1.33 | (2,4,2,3,3,5,4) |
| Hexafluorethane | ε | | | | | C2F6 is a proxy for C3F6 (recommended by G. Wernet) | chemicals | organics | No | GLO | hexafluorethane, at plant | 2.62E-02 | kg | Hyung-Gon (2002) | 1 | 1.33 | (2,4,2,3,3,5,4) |
| Phthalic anhydride | ε | | | | | Phthalic anhydride is a proxy für dibutyl phthalate (recommended by G. Wernet) | chemicals | organics | No | RER | phthalic anhydride, at plant | 2.91E-01 | kg | Hyung-Gon (2002) | 1 | 1.33 | (2,4,2,3,3,5,4) |
| Silica | ε | | | | | | construction materials | additives | No | DE | silica sand, at plant | 2.18E-01 | kg | Hyung-Gon (2002) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Acetone | ε | | | | | Solvent, internally recycled (Brodd 2002), Recycling rate: 99% (Expert guess H-J. Althaus) | chemicals | organics | No | RER | acetone, liquid, at plant | 1.44E-02 | kg | Hyung-Gon (2002) | 1 | 1.25 | (2,4,2,3,1,5,4) |
| Infrastructure, chemical plant | ε | | | | | Ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |
| Electricity | ε | | | | | Mechanical drive for pumping slurry, coating, coiling, cutting | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | | evaporating solvent, heating seperator base materials | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 1.93E-01 | MJ | Assumption: Specific heat of the Seperator is equals to specific heat the anode in the dataset "Anode, lithium-ion battery" | 1 | 1.33 | (4,4,2,3,1,5,1) |
| Transport lorry | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 9.84E-02 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 5.25E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Separator, lithium-ion battery, at plant: Output | ε | Disposal coated cathode | 5% loss, according to ecoinvent assumption for missing information, included waste from slitting the coils | waste management | municipal incineration | No | CH | disposal, residues, shredder fraction from manual dismantling, in MSWI | 5.39E-02 | kg | 5% loss, according to ecoinvent assumption for missing information | 1 | 1.64 | (5,4,2,3,3,5,6) |
| | ε | Acetone | evaporating solvent | air | unspecified | | | Acetone | 1.44E-02 | kg | equal the amount aceton input | 1 | 1.63 | (4,4,2,3,1,5,16) |
| | ε | Waste heat to air | Heat and electric power | air | unspecified | | | Heat, waste | 7.20E-03 | MJ | calculated from eletricity input | 1 | 1.33 | (4,4,2,3,1,5,13) |
| | ε | Seperator, lithium-ion battery | | electronics | component | No | CN | separator, lithium-ion battery, at plant | 1.00E+00 | kg | | | | |

A porous polyethylene film is coated with a slurry consisting of a copolymer (polyvinylidedfluoride and hexafluorpropylene), dibutyl phthalate and silica dissolved in acetone [21]. Thermal heat energy is used to heat up the slurry to 130°C and to evaporate acetone and to dry the coated cathode in a dry channel ($H_2O$ content < 20ppm) [20].

**Table S16.** Input-output table for the production of a single cell.

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Cathode | ε | single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant: Input | | | | Based on LiMn2O4 | electronics | component | No | CN | Cathode, lithium-ion battery, lithium manganese oxide, at plant | 3.27E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,3) |
| Anode | ε | | | | | Based on graphite | electronics | component | No | CN | Anode, lithium-ion battery, graphite, at plant | 4.01E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,3) |
| Separator | ε | | | | | coated polethylene film | electronics | component | No | CN | separator, lithium-ion battery, at plant | 5.37E-02 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,3) |
| Electrolyt: Solvent | ε | | | | | Ethylencarbonate | chemicals | organics | No | CN | ethylene carbonate, at plant | 1.60E-01 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,3) |
| Electrolyt: Salt | ε | | | | | 1 molar solution of LiPF6 in EC | chemicals | inorganics | No | CN | lithium hexafluorophosphate, at plant | 1.90E-02 | kg | calculated | 1 | 1.24 | (2,4,1,3,1,5,3) |
| Aluminium electrode tab | ε | | | | | Electrode, current collector, aluminium | metals | extraction | No | RER | aluminium, production mix, wrought alloy, at plant | 1.65E-02 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,12) |
| Aluminium sheet rolling | ε | | | | | thickness of the Alu-tab: 1 mm | metals | processing | No | RER | sheet rolling, aluminium | 1.65E-02 | kg | Measurement M. Gauch, Kokam cell | 1 | 3.06 | (2,4,1,3,1,5,9) |
| Inert atmosphere | ε | | | | | Nitrogen | chemicals | inorganics | No | RER | nitrogen, liquid, at plant | 1.00E-02 | kg | Assumption: R. Widmer, M. Gauch | 1 | 1.32 | (4,4,1,3,1,5,4) |
| Package | ε | | | | | Assumption: Polyethylen envelope | plastics | polymers | No | RER | polyethylene, LDPE, granulate, at plant | 7.33E-02 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,4) |
| Package | ε | | | | | Polyethylen envelope production | plastics | processing | No | RER | extrusion, plastic film | 7.33E-02 | kg | Measurement M. Gauch, Kokam cell | 1 | 1.24 | (2,4,1,3,1,5,4) |
| Infrastructure, chemical plant | ε | | | | | ecoinvent standard dataset | chemicals | organics | Yes | RER | chemical plant, organics | 4.00E-10 | unit | ecoinvent standard dataset | 1 | 3.36 | (5,5,2,3,3,5,9) |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electricity | ε | | | | Calendaring anode, seperator, cathode | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 2.00E-03 | kWh | Estimation by M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Electricity | ε | | | | charge of the single cell, 70% (of 0.148 kWh) | electricity | supply mix | No | CN | electricity, medium voltage, at grid | 1.04E-01 | kWh | Estimation by M. Gauch, R. Widmer | 1 | 1.48 | (4,5,3,5,3,5,2) |
| Process heat | ε | | | | Heating anode, cathode and seperator, | natural gas | heating systems | No | RER | heat, natural gas, at industrial furnace >100kW | 6.52E-02 | MJ | calculated from specific heat of the base materials based on the specific heat of the components | 1 | 1.32 | (4,4,1,3,1,5,1) |
| Transport lorry | ε | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | road | No | RER | transport, lorry >16t, fleet average | 2.78E-02 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| Transport train | ε | | | | according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe) | transport systems | train | No | RER | transport, freight, rail | 1.67E-01 | tkm | ecoinvent standard distances | 1 | 3.20 | (5,5,5,2,5,5,5) |
| | | battery, lithium manganese oxide/graphite, at | ε | single cell | 5% loss, according to ecoinvent assumption for missing information, | waste management | recycling | No | GLO | disposal, Li-ions batteries, mixed technology | 5.25E-02 | kg | 5% loss, according to ecoinvent assumption for missing information | 1 | 1.58 | (5,4,1,3,1,5,6) |
| | | | ε | Waste heat to air | Heat and electric power | air | unspecified | | | Heat, waste | 3.80E-01 | MJ | calculated from eletricity input | 1 | 1.32 | (4,4,1,3,1,5,13) |
| | | | ε | singel cell, lithium ion battery | | electronics | component | No | CN | single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant | 1.00E+00 | kg | | | | |

Cathode, separator and anode are calendared, slit to size, winded and packed in a polyethylene envelope. In an inert atmosphere, the $LiPF_6$ dissolved in the electrolyte is added to the electrode [17].

**Table S17.** Input-output table for the production of a battery pack.

| General Flow information | | | | | | | Representation in ecoinvent | | | | | | | | Uncertainty information | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | □ | Process Name | □ | Output | | Remarks | Category | Sub category | Infrastructure | Location | Modul name in ecoinvent | Mean value | Unit | Source mean value | Type | StDv 95% | General Comment |
| Single cell | ε | battery, Lilo, rechargeable, prismatic, at plant: Input | | | | weight per kg battery | electronics | component | No | CN | single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant | 7.99E-01 | kg | Estimation M. Gauch, R. Widmer | 1 | 1.16 | (1,4,1,3,1,4,3) |
| Steelbox, material | ε | | | | | unalloyed steel | metals | extraction | No | RER | reinforcing steel, at plant | 1.45E-01 | kg | Estimation M. Gauch, R. Widmer | 1 | 1.27 | (2,4,1,3,3,4,12) |
| steelbox, production | ε | | | | | steel, sheet rolling | metals | processing | No | RER | sheet rolling, steel | 1.45E-01 | kg | Estimation M. Gauch, R. Widmer | 1 | 1.27 | (2,4,1,3,3,4,3) |
| Battery management system, mounting | ε | | | | | mounting | electronics | module | No | GLO | printed wiring board, surface mounted, unspec., solder mix, at plant | 3.38E-03 | kg | Estimation M. Gauch, R. Widmer | 1 | 1.16 | (1,4,1,3,1,4,3) |
| Data cable | ε | | | | | | electronics | component | No | GLO | cable, data cable in infrastructure, at plant | 3.73E-01 | m | Estimation M. Gauch, R. Widmer | 1 | 1.19 | (3,4,1,3,1,4,3) |
| 3 phase cable | ε | | | | | | electronics | component | No | GLO | cable, three-conductor cable, at plant | 2.50E-02 | m | Estimation M. Gauch, R. Widmer | 1 | 1.19 | (3,4,1,3,1,4,3) |
| Testing/activating | ε | | | | | Electricity | electricity | production mix | No | UCTE | electricity, low voltage, production UCTE, at grid | 1.08E-01 | kWh | Estimation M. Gauch, R. Widmer, 1 batter charge | 1 | 1.48 | (4,5,3,5,3,5,2) |
| metal working factory | ε | | | | | ecoinvent standard dataset | metals | general manufacturing | Yes | RER | metal working factory | 4.58E-10 | unit | reference unit of metal working factory according to Ecoinvent (Report 23) | 1 | 3.36 | (5,5,2,3,3,5,9) |
| Transport ship | ε | | | | | Assumption: single cell imported from China, battery pack produced in Europe | transport systems | ship | No | OCE | transport, transoceanic freight ship | 7.81E+00 | tkm | ecoinvent standard distances | 1 | 2.12 | (3,4,1,2,3,5,5) |
| Transport lorry | ε | | | | | Assumption: single cell imported from China, battery pack produced in Europe | transport systems | road | No | RER | transport, lorry >16t, fleet average | 1.02E+00 | tkm | ecoinvent standard distances | 1 | 2.12 | (3,4,1,2,3,5,5) |
| | | battery, Lilo, rechargeable, prismatic, at plant: Output | ε | Waste heat to air | | Electric power | air | unspecified | | | Heat, waste | 3.87E-01 | MJ | calculated from eletricity input | 1 | 1.60 | (4,4,1,2,4,4,13) |
| | | | ε | Lithium-ion battery 2009 | | | electronics | module | No | GLO | battery, Lilo, rechargeable, prismatic, at plant | 1.00E+00 | kg | | | | |

Finally, single cells, the battery management system and cables are assembled in a steel box.

The production of concentrated lithium brine and $Li_2CO_3$ takes place in Chile. Therefore, we used an electricity mix from Brasil as a proxy for an electricity mix from Chile. For all other datasets, except assembly of the battery, we assumed the production in China. Thus, a Chinese electricity mix was utilized for these datasets. Cell assembly is expected to be accomplished in Europe, using therefore a European electricity mix [22].

Transport distances for the production of $Li_2CO_3$ are calculated with provided data from SEIA-CONAMA [7]. For all datasets produced in China, we hypothesise equal average transport distances for China as for Europe. Thus, European standard transport distances are balanced as recommended by ecoinvent [1]. All single components are transported by ship and road to Europe for the cell assembly.

Infrastructure is incorporated by accounting a chemical plant [23] or a metal working factory [24] for most datasets (for detailed information see supporting information).

**Table S18.** Material composition and weight of the components in kg of the internal combustion engine car (ICEV) and the battery powered electric car (BEV).

| Material composition | Glider | ICEV drive train | Total ICE-V | Glider | BEV drive train | Battery | Total EV |
|---|---|---|---|---|---|---|---|
| Steel and iron | 519.0 | 114.6 | 633.6 | 519.0 | 39.0 | 0.0 | 558.0 |
| Synthetics | 127.0 | 41.0 | 168.0 | 127.0 | 2.0 | 0.0 | 129.0 |
| Fuel/oil/lubricants | 6.0 | 58.0 | 64.0 | 6.0 | 0.0 | 0.0 | 6.0 |
| Light metals | 3.0 | 48.7 | 51.7 | 3.0 | 32.7 | 0.0 | 35.7 |
| Tyres and rubber | 41.0 | 3.0 | 44.0 | 41.0 | 0.0 | 0.0 | 41.0 |
| Glass | 30.0 | 0.0 | 30.0 | 30.0 | 0.0 | 0.0 | 30.0 |
| Electric motors, cables | 24.0 | 1.0 | 25.0 | 24.0 | 6.0 | 0.0 | 30.0 |
| Base metals | 2.0 | 17.0 | 19.0 | 2.0 | 19.0 | 0.0 | 21.0 |
| Insulation | 16.0 | 0.0 | 16.0 | 16.0 | 0.0 | 0.0 | 16.0 |
| Paints | 4.2 | 0.0 | 4.2 | 4.2 | 0.0 | 0.0 | 4.2 |
| Others | 2.0 | 0.0 | 2.0 | 2.0 | 0.0 | 300.0 | 302.0 |
| Total | 774.2 | 283.3 | 1057.5 | 774.2 | 98.7 | 300.0 | 1172.9 |

**Table S19.** Environmental burden assessed with 4 different impact assessment methods for E-mobility and mobility with an ICEV.

| | EI 99 H/A points | | CED $10^3$ MJ eq. | | GWP $10^3$ kg $CO_2$ eq. | | ADP kg Sb eq. | |
|---|---|---|---|---|---|---|---|---|
| | **BEV** | **ICEV** | **BEV** | **ICEV** | **BEV** | **ICEV** | **BEV** | **ICEV** |
| Total | 1570 | 2350 | 480 | 547 | 24.3 | 34.7 | 190 | 241 |
| Road | 134 | 134 | 31.7 | 31.7 | 1.08 | 1.08 | 13.7 | 13.7 |
| Glider | 270 | 270 | 66.5 | 66.5 | 3.74 | 3.74 | 30.4 | 30.4 |
| Drive-train | 120 | 127 | 21.9 | 27.8 | 1.35 | 1.46 | 9.68 | 12.2 |
| Maintenance, disposal car | 81.5 | 84.4 | 23.7 | 24.0 | 1.14 | 1.17 | 9.80 | 10.1 |
| Li-ion battery | 240 | 0 | 31.2 | 0 | 1.80 | 0 | 14.6 | 0 |
| Operation | 720 | 1740 | 305 | 397 | 15.2 | 27.2 | 112 | 174 |

**Table S19.** Environmental burden assessed with Ecoindicator 99 H/A (EI 99 H/A, unit: points), non renewable cumulated energy demand (CED, unit: MJ equivalents (MJ-eq.)), global warming potential (GWP, unit: kg carbon dioxide equivalents (kg $CO_2$ eq.)) and abiotic depletion potential (ADP, unit: kg antimony equivalents (kg Sb eq.)).

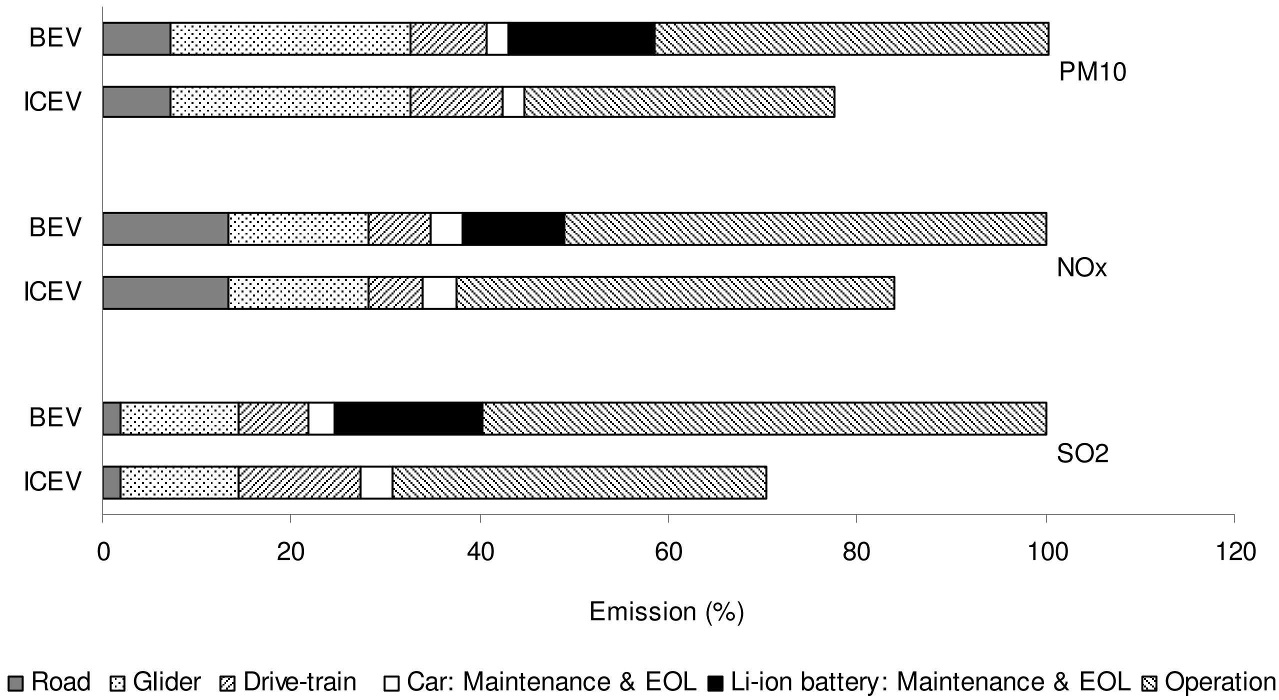



**Figure S1**. Shares of life cycle inventory results for sulfur dioxide (SO2), nitrogen oxides (NOx) and cumulative particulates (PM10) caused by battery powered electric car (BEV; the BEV is set as 100%) and an internal combustion engine car (ICEV, value in % of the BEV). Road includes construction, maintenance and end of life treatment (EOL). All absolute values of the components are provided in the supporting information.

**Table S20.** Sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$) and cumulative particulates ($PM_{10}$) for E-mobility and mobility with an ICEV.

| | **Mobility with a BEV** | | | | | | **Mobility with an ICEV** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | | $NO_x$ | | $PM_{10}$ | | $SO_2$ | | $NO_x$ | | $PM_{10}$ | |
| | kg | % | kg | % | kg | % | kg | % | kg | % | kg | % |
| Total E-mobility | 83.7 | 100 | 49.5 | 100 | 16.2 | 100 | 59.0 | 70.4 | 41.5 | 83.9 | 12.5 | 77.6 |
| Road | 1.55 | 1.85 | 6.63 | 13.4 | 1.15 | 7.13 | 1.55 | 1.85 | 6.63 | 13.4 | 1.15 | 7.13 |
| Glider | 10.5 | 12.5 | 7.36 | 14.9 | 4.12 | 25.5 | 10.5 | 12.5 | 7.36 | 14.9 | 4.12 | 25.5 |
| Drive-train | 6.21 | 7.42 | 3.20 | 6.47 | 1.31 | 8.10 | 10.8 | 13.0 | 2.76 | 5.59 | 1.58 | 9.80 |
| Maintenance, disposal car | 2.41 | 2.88 | 1.69 | 3.41 | 0.364 | 2.25 | 2.92 | 3.48 | 1.80 | 3.64 | 0.384 | 2.38 |
| Li-ion battery | 13.1 | 15.7 | 5.33 | 10.8 | 2.51 | 15.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operation | 49.9 | 59.7 | 25.3 | 51.1 | 6.75 | 41.8 | 33.2 | 39.6 | 22.9 | 46.4 | 5.30 | 32.8 |

**Table S20**. Inventory data of emission values for sulphur dioxide (SO2), nitrogen oxides (NOx) and cumulative particulates (PM10). The values for the life cycle battery powered electric vehicle (BEV) and mobility with an internal combustion engine vehicle (ICEV) refer to a covered distance of 150`000 km. The total emissions of the BEV are set as baseline (100%).

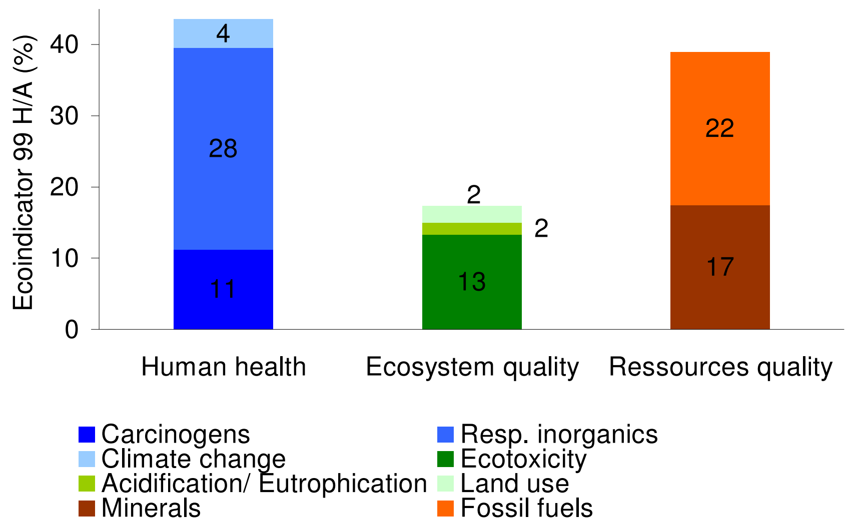



**Figure S2.** Life cycle impact assessment results for the Li-ion battery evaluated with the Ecoindicator 99 H/A. The score is split into the 3 damage categories Human Health, Ecosystem Quality and Ressource Quality and their subcategories.

**Table S21.** Absolute and relative values of environmental burden assessed with 4 different impact assessment methods for the production of 1 kg Li-ion battery.

| | EI 99 H/A | | CED | | GWP | | ADP | |
|---|---|---|---|---|---|---|---|---|
| | points | % | MJ eq. | % | kg $CO_2$ eq. | % | kg Sb eq. | % |
| Total Li-ion battery | 0.801 | 100 | 104 | 100 | 6.00 | 100 | 0.0485 | 100 |
| Battery pack | 0.162 | 20.3 | 27.6 | 26.5 | 1.61 | 26.8 | 0.0126 | 25.9 |
| Printed wiring board | 0.0630 | 7.86 | 13.7 | 13.1 | 0.853 | 14.3 | 0.00617 | 12.7 |
| Reinforcing steel | 0.0150 | 1.88 | 3.31 | 3.18 | 0.212 | 3.53 | 0.00185 | 3.81 |
| Three conductor cable | 0.0312 | 3.89 | 2.06 | 1.97 | 0.083 | 1.39 | 0.000880 | 1.81 |
| Single cell | 0.638 | 79.7 | 76.5 | 73.5 | 4.39 | 73.2 | 0.0359 | 74.1 |
| Anode | 0.403 | 50.3 | 19.6 | 18.8 | 0.870 | 14.5 | 0.0113 | 23.4 |
| Copper | 0.346 | 43.2 | 5.24 | 5.03 | 0.339 | 5.65 | 0.00259 | 5.33 |
| Graphite | 0.0296 | 3.70 | 10.6 | 10.2 | 0.345 | 5.75 | 0.00709 | 14.6 |
| Rest anode | 0.0273 | 3.41 | 3.81 | 3.66 | 0.187 | 3.11 | 0.00165 | 3.41 |
| Separator | 0.0170 | 2.12 | 4.69 | 4.51 | 0.257 | 4.29 | 0.00208 | 4.28 |
| Cathode | 0.131 | 16.4 | 31.4 | 30.1 | 2.17 | 36.2 | 0.0135 | 27.8 |
| Aluminium | 0.082 | 10.3 | 16.8 | 16.1 | 1.28 | 21.3 | 0.00734 | 15.1 |
| $LiMn_2O_4$ | 0.0448 | 5.59 | 13.0 | 12.5 | 0.831 | 13.8 | 0.00552 | 11.4 |
| Rest cathode | 0.00425 | 0.531 | 1.59 | 1.52 | 0.0635 | 1.06 | 0.000633 | 1.31 |
| Ethylene carbonate | 0.0176 | 2.20 | 5.03 | 4.83 | 0.185 | 3.09 | 0.00220 | 4.54 |
| $LiPF_6$ | 0.0304 | 3.79 | 6.05 | 5.81 | 0.389 | 6.47 | 0.00248 | 5.11 |
| LiF | 0.00203 | 0.254 | 0.350 | 0.336 | 0.0257 | 0.428 | 0.000160 | 0.329 |
| $PCl_5$ | 0.00499 | 0.624 | 1.78 | 1.71 | 0.0851 | 1.42 | 0.000725 | 1.49 |
| $Mn_2O_3$ | 0.0162 | 2.03 | 5.41 | 5.20 | 0.364 | 6.06 | 0.00212 | 4.37 |
| $Li_2CO_3$ | 0.0103 | 1.29 | 1.84 | 1.77 | 0.135 | 2.25 | 0.000904 | 1.86 |
| Conc. Lithium brine | 0.00072 | 0.0900 | 0.0987 | 0.0948 | 0.0653 | 0.109 | 0.0000438 | 0.0903 |

**Table S21.** Environmental burden assessed with Ecoindicator 99 H/A (EI 99 H/A, unit: points), non renewable cumulated energy demand (CED, unit: MJ equivalents (MJ-eq.)), global warming potential (GWP, unit: kg carbon dioxide equivalents (kg $CO_2$ eq.)) and abiotic depletion potential (ADP, unit: kg antimony equivalents (kg Sb eq.)).

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